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DUANE ARNOLD ENERGY CENTER
CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY

ANNUAL REPORT

January 1988 - December 1988

Submitted by

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INTRODUCTION

This report presents the results of the physical, chemical and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 15th year of station operation (January 1988 to December 1988).

The Duane Arnold Energy Center Operational Study was implemented in mid-January 1974. Prior to plant start-up, extensive preoperational data were collected from April 1971 to January 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of 15 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-

northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers, which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water, and were first implemented in January 1974.[4-17]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical, chemical and biological studies in and adjacent to the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities adjacent to the discharge.

STUDY PLAN

During the operational phase of the study, sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) Upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2), 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3), and 4) adjacent to Comp Farm, about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering, University of Iowa. From January 1979 through December 1983 samples were

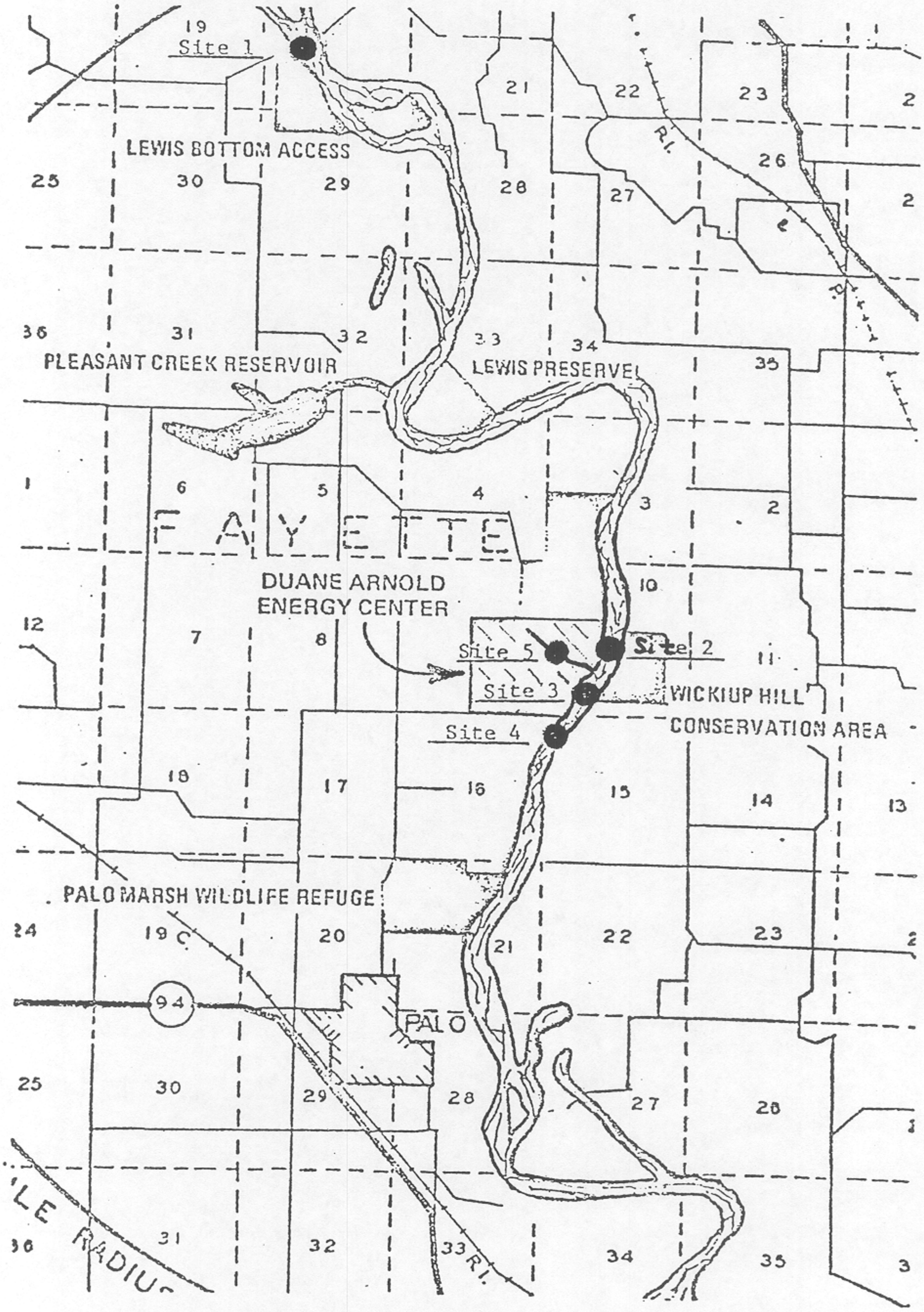

Figure 1. Location of Operational Sampling Sites

collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analysis.

Samples for routine chemical, physical and biological analysis were taken twice per month while other studies were conducted seasonally. The following are discussed in this report:

I. <u>General Water Quality Analysis</u>

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (total and fecal)

II. <u>Additional Chemical Determinations</u>

A. Frequency: twice yearly

B. Location: at all five stations

C. Parameters measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic studies

1. Frequency: summer and fall
2. Location: at all five stations

B. Asiatic Clam (Corbicula) survey

1. Frequency: twice yearly
2. Location: upstream and downstream of the plant, intake bay, and cooling tower basin.

C. Impingement studies

1. Frequency: daily
2. Location: intake structure

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

Mean monthly flows in the Cedar River during the period January-December 1988 were consistently lower than those present in 1987, ranging from 182% of the median monthly discharge in January to 24% in July. Estimated mean flow for the year was ca. 1,545 cfs, the second lowest mean flow observed during the 1972-1988 period, and less than one third of the 17 year average flow of ca. 4,815 cfs. Mean monthly discharges at the Cedar Rapids gauging station ranged from 517 cfs in October to 3,974 cfs in March. Mean monthly discharges in 1988 were classified as deficient (less than the 25% quartile) from June through December. Winter flows varied from 1,140 to ca. 5,000 cfs until early March and then rose to a spring high of 6,890 cfs on March 8, 1988. Flows remained relatively low from mid-March through late May, ranging from ca. 2,100 to 4,200 cfs and then declined to a spring low of 786 cfs on June 14. Summer flows remained very low, ranging from ca. 1,150 cfs in late June to 418 cfs on September 15. Fall and winter flows were also well below normal, ranging from 928 cfs on November 27 to 364 cfs on December 9. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient river temperatures during 1988 ranged from 0.0°C (32.0°F) to 28.0°C (82.4°F). In spite of the unusually warm summer, the maximum ambient temperature observed upstream of the plant (Station 1) on July 14 was somewhat lower than that of the previous year. A maximum downstream temperature of 29°C (84.2°F) was observed one-half mile below the plant (Station 4) on August 12. The highest discharge canal (Station 5) temperature observed during the period was 31.5°C (88.7°F), also recorded on August 12. The Duane Arnold Energy Center was off-line from October through December and temperature differentials between upstream and downstream river locations, which are frequently high at this time, were usually minimal. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 18°C (32.4°F) was observed on January 28.

The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 4°C (7.2°F) was measured on January 14. A maximum temperature elevation at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) of 2°C (3.6°F) was observed on three occasions in August and September. There was no instance in which a temperature elevation in excess of the Iowa water quality standard of 3°C was observed. No other samples taken at Station 4 exhibited temperature differentials in excess of 1.5°C (2.7°F) above ambient. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

<u>Turbidity</u> (Table 4)

In spite of very low river flows, average turbidity values were similar to those of the previous year. Maximum levels were lower however. Peak values of 72-78 NTU occurred at all river locations in early March during a period of high river flow. In general, highest values occurred during periods of runoff while low values (3-13 NTU) occurred during the winter. Most turbidity values in the discharge canal were similar to those observed in river samples but maximum values were greater. A maximum discharge canal turbidity of 370 NTU was observed on August 26.

<u>Solids</u> (Tables 5-7)

Solids determinations included total, dissolved and suspended. Total solids values in upstream river samples were generally slightly lower than observed in 1987. Values ranged from 270 to 460 mg/L, with the majority falling between 300 and 400 mg/L.

Dissolved solids values were relatively low throughout the year. Upstream values ranged from 140 to 400 mg/L. Lowest values occurred during the extended period of low river flow in the summer and early fall. High values occurred in the winter. Dissolved solids values at Station 3, 140 feet downstream of the discharge canal, were higher than values observed upstream of the discharge canal. A maximum downstream value of 800 mg/L was observed at Station 3 on June 27. In spite of extremely low river flow, dissolved solids values at Station 4, one-half mile below the plant, were only slightly higher than upstream levels, ranging from ca. 180-210 mg/L from late June through early September to 410 mg/L in January.

Suspended solids values at all river locations were low, ranging from 3 to 160 mg/L. Low values occurred in January and early February, while high values occurred in early March during a period of relatively high runoff.

Due to concentration in the blowdown, total and dissolved solids values in the discharge canal were consistently higher than in the river samples. Maximum total solids concentrations of 2,400 mg/L were observed in the discharge canal in March, while a minimum value of 270 mg/L was observed on October 20 when the station was not operating.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1988 were relatively high ranging from 6.5 to 19.3 mg/L (80 to 134% saturation). Dissolved oxygen concentrations in excess of saturation were frequently observed in the river from April through December. Maximum dissolved oxygen concentrations occurred from October through December.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 4.5 to 14.4 mg/L (56 to 110% saturation). Lowest values occurred during the summer. Highest values were observed from October through December when the station was not operating.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations ranged from <1 to 20 mg/L. Lowest values (<1 mg/L) were consistently present at all river locations from late April through December. Maximum levels occurred in January and February when algal activities were minimal.

Alkalinity, pH, Hardness (Tables 10-14)

These closely related parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Total alkalinity values in river samples were relatively low in 1988 ranging from 62 to 264 mg/L. Lowest values occurred from June through October during the period of extended low flow. High values occurred during the winter months.

Unlike most earlier years, carbonate alkalinity was consistently present in river samples from late April through December. Values ranged from <1 mg/L during the winter and early spring period to 36 mg/L in early September.

Values for pH in river samples were also relatively high ranging from 7.6 to 9.5. As in previous years, highest values usually occurred during the summer and fall while lowest values occurred in the winter.

The lower carbon dioxide and higher carbonate and pH values observed during 1988 appeared to be related to the increased photosynthetic activity accompanying the lower river discharge present during most of the year.

Total hardness values in the upstream river generally paralleled total alkalinity levels. The highest values (300-360 mg/L) generally occurred during the winter, while low values of ca. 100-150 mg/L occurred during the summer and early fall.

The low total alkalinity and hardness levels which occurred during the extended dry period in 1988 were similar to those observed in 1987 and appeared to be related to the rapid downward movement of surface water through the dry unconsolidated surficial deposits into the shallow aquifers feeding the Cedar River. This rapid movement of water shortens its residence time in the surface deposits and shallow aquifer, and reduces the time available for the solubilization of calciferous materials. In years with normal rainfall, low total alkalinity and hardness levels usually occur during runoff while high values occur during the winter.

Hardness values in the discharge canal were consistently higher during periods of station operation than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 90 mg/L in May to 1450 mg/L in March. Levels downstream of the station were generally higher than upstream values during periods of station operation. Total alkalinity values in the discharge canal were generally lower than river values when the station was operational. Most pH values in the discharge canal ranged from 7.9 to 8.9. However, extreme values ranging from 3.3 to 9.9 were present. These extreme values, 9.9 on October 6 and 3.3 on November 2, appeared to be related to construction or maintenance activities in the cooling tower basins and were not reflected at downstream river locations.

<u>Phosphates</u> (Tables 15 and 16)

In general, total phosphate concentrations in upstream river samples were slightly higher than those observed during 1986 and 1987 (Table 27). Ambient concentrations in the river ranged from 0.1 mg/L in late April and May to 0.6 mg/L in January. Levels in the discharge canal were frequently higher than those observed in the river. Most values ranged from 0.5 to 2.5 mg/L but an extreme concentration of 120 mg/L was observed on October 6 which was apparently related to maintenance activities in the cooling tower basins.

Orthophosphate concentrations in river samples ranged from <0.1 mg/L from late April through November to 0.4 mg/L in February. As in previous years, orthophosphate concentrations were lower than total phosphate levels and as expected, the greatest differential between phosphate forms coincided with large plankton populations and the resultant uptake of orthophosphate.

<u>Ammonia</u> (Table 17)

Ammonia concentrations in the river continued to be very low throughout 1988. Concentrations were consistently below <0.01 mg/L (as N) from late March through December. Highest concentrations of 0.3 to 0.6 mg/L (as N) occurred from January through early March. Low values consistently occurred during the dry summer period.

<u>Nitrate</u> (Table 18)

Nitrate concentrations were substantially lower in 1988 than during the past few years due primarily to the extended dry weather and low river flows present. During the current year, nitrate values in river samples ranged from ca. <0.1 mg/L (as N) from mid-July through early September to 9.9 mg/L (as N) in mid-January. The average nitrate nitrogen concentration at Station 1, located at Lewis Access upstream of the plant, was 2.8 mg/L, the lowest average value since

1976. Concentrations in excess of 2 mg/L (as N) were observed from January through May and from mid-November through December.

Nitrate concentrations were frequently higher in the discharge canal than in river samples, due to reconcentration in the blowdown. A maximum nitrate concentration of 25 mg/L (as N) was observed in the discharge canal in March.

Iron (Table 19)

Iron concentrations in the river were similar to those observed in 1986 and 1987. Concentrations in river samples in 1988 ranged from 0.07 to 2.2 mg/L. Concentrations in excess of 1 mg/L occurred in March in conjunction with spring runoff. Low values of 0.2 mg/L or less commonly occurred during the winter and in dry periods from July through December. As in previous years, high iron concentrations were usually observed in association with high turbidity and suspended solids values, indicating that most of the iron present is in the suspended form rather than in solution. Iron levels were consistently higher in the discharge canal throughout 1988. A maximum iron value of 6.0 mg/L was observed in the canal in November.

Biological Conditions

Biochemical Oxygen Demand (Table 20)

Average five day biochemical oxygen demand (BOD_5) values were the highest observed since the study began in 1972 (Table 27). Levels in the river ranged from <1 to 25 mg/L. Because of minimal runoff values observed during the winter and spring were low ranging from <1 to 5 mg/L. High BOD values, ranging from 12 to 25 mg/L, were consistently observed from late May through October when river flows were low and large algal populations were present.

Coliform Organisms (Tables 21 and 22)

Determination of total and fecal coliform bacterial populations were reinstituted in 1984 after being discontinued in 1978. In general upstream coliform values were lower and exhibited less variation than those of the previous three years. Highest counts usually occurred during February and March and generally coliform counts upstream and downstream of the station were similar. However, the maximum total coliform count of 27,000 organisms/100 ml, observed in the mixing zone 140 feet downstream of the discharge canal (Station 3) on June 8, was far higher than upstream values. The maximum observed fecal coliform level, 2000 organisms/100 ml, was observed 1/2 mile downstream of the plant on the same date. Low fecal coliform counts of 10 or less organisms/100 ml were frequently observed during the October-December period.

ADDITIONAL STUDIES

In addition to the routine monthly studies, a number of seasonal limnological and water quality investigations were conducted during 1988. The studies discussed here include additional chemical determinations, benthic studies, and Asiatic clam (Corbicula) and impingement surveys.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on March 23 and June 27. The samples were analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury and zinc. In general, concentrations in river samples fell within the expected ranges and were similar to those observed during the previous year.

Concentrations of most heavy metals in the 1988 samples remained low. With the exception of manganese, heavy metal values were below detection limits in all upstream river samples. Manganese, zinc and copper were occasionally present in samples taken downstream of the station but no violations of water quality standards[18] were observed.

Reconcentration of solids in the blowdown resulted in increased chromium, copper, manganese, zinc and chloride levels in the discharge canal. High sulfate concentrations were also observed in the discharge canal with lesser increases at the downstream locations due to the addition of sulfuric acid for pH control in the cooling water. The results of additional chemical determinations are given in Table 23.

Benthic Studies

Bottom samples were taken at two locations, upstream and downstream of the station, on May 2 and November 10, 1988, by means of a Ponar dredge. No organisms were found in any of the samples. These results are compatible with earlier studies that indicated the shifting sand and silt bottom supports a benthic community of very limited size and diversity. Only three organisms were found in the 1987 Ponar dredge samples and no organisms were found in the 1986 samples.

Three artifical substrates (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal in May and September. These substrates were collected in July and November following a six week colonization period. Eleven of the original 15 substrates were recovered following colonization that summer, and all of the 15 fall samples were recovered.

As in previous years, artificial substrate samples were characterized by far greater numbers and species diversity than the natural substrate (Ponar dredge) samples. A total of 32 taxa were identified during the two sampling periods: 26 in July and 27 in November. Midge and caddisfly (tricoptera) larvae were the most common organisms observed on the July river substrates. The July discharge canal samples were dominated by midge (chironomid) larvae. Midge and caddisfly larvae and stonefly (plectoptera) nymphs were the most common organisms on the November river substrates. The November discharge canal substrates contained few organisms, principally snails. In general, there was little difference in the composition of benthic populations between upstream and downstream locations although Station 2, upstream of the intake, and Station 4, one half mile below the plant, generally supported larger numbers of caddisfly and midge larvae than the other sampling locations.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Table 24.

Asiatic Clam Survey

In past years several power generation facilities have experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam is common in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy Center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine Cedar River monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been collected on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1987 investigations.

The Corbicula surveys conducted during 1988 continued to be negative. Samples were taken on May 2 and November 10, 1988. During the May survey an inspection of sediment samples for the presence of Corbicula was conducted at the intake structure, both cooling tower basins, and in the river upstream and downstream of the station. No Corbicula were observed.

In November, Ponar dredge samples were collected in front of the traveling bar screens at the intake structure, and in the river upstream and downstream of the station were inspected for the presence of Asiatic clams. No clams were found in any of the samples collected.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1988, as reported by Iowa Electric personnel, continued to be low although counts were somewhat higher than those observed in 1986 and 1987. Daily counts conducted by DAEC station personnel indicated a total of 539 fish were impinged during 1988. Highest impingement rates continued to occur during the winter. During the months of January, February, March and December, 388 fish were removed from the trash baskets. The month with the highest impingement rate was December when 183 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

The results of the studies conducted on the Cedar River during 1988 continue to support the conclusion of earlier investigations that operation of the Duane Arnold Energy Center has a minimal impact on the limnology and water quality of the river. This has been especially relevant during 1987 and 1988 when river flows were substantially below normal and the effects of station discharge on the downstream river would be expected to be more significant. The mean river flows of ca. 2,625 and 1,546 cfs observed in 1987 and 1988 respectively were the lowest present since 1977, and substantially below the average of ca. 4,815 cfs present during the 17 year study period. During 1988 temperature increases in the discharge canal were as much as 18^{o}C (32.4^{o}F) above ambient river levels. However, downstream temperatures one-half mile below the plant averaged only 1^{o}C (1.8^{o}F) above ambient during periods of station operation and never exceeded upstream temperatures by more than 2^{o}C (3.6^{o}F). Even within the mixing zone (Station 3), temperature differentials (Δ T) never exceeded 4^{o}C (7.2^{o}F) and averaged only 1.4^{o}C (2.5^{o}F). At no time were observed temperature differentials in violation of water quality standards. Several other parameters, i.e., dissolved solids, hardness, phosphate, nitrate, and iron were present in substantially higher concentrations in the discharge canal during periods of station operation than at upstream locations, due to reconcentration in the blowdown discharge. Concentrations of these substances were also usually higher in the mixing zone (Station 3). Increases downstream of the mixing zone at Station 4 were substantially less although greater than those observed in 1987. Average values for the above mentioned parameters during periods of station operation are summarized in Table 26.

During the 1988 study there was only one incident where an exceedance of the applicable Iowa Water Quality Standards[18] was observed which could possibly be attributed to activities at the Duane Arnold Energy Center. The Cedar River in the vicinity of the Duane Arnold Energy Center is designated as a Class "A" and "B" stream. Class A waters are protected for primary contact and include limits on fecal coliform content during the April-October period. These standards apply to coliform levels related to wastewater discharges rather than surface runoff and state that "in no case shall fecal coliform levels downstream from a discharge which may contain human pathogens be more than 200 organisms/100 ml higher than the background level." A review of the 1988 fecal coliform data indicate that a single coliform value in excess of this number was observed on June 8 at Station 4, 1/2 mile below the plant, but the source of this high level cccould not be determined. Fecal coliform levels downstream of the station could not be determined during most of the June-August period due to high non-coliform background growth but downstream total coliform levels well in excess of upstream values were frequently observed from late June to early August indicating that significant upstream/downstream fecal coliform differentials may have persisted during this period.

From June through October values for pH were frequently in excess of the criteria of 9.0 for Class "B" waters. These levels, observed both upstream and downstream of the station, were due to high algal photosynthesis resulting from the low flow conditions present and were not related to station operation.

Several other parameters in addition to pH were markedly influenced by the low flows present during 1988. Dissolved oxygen concentrations were consistently in excess of saturation from late May through December as a result of high algal photosynthetic activity. Algal blooms also resulted in the high BOD levels observed during the summer and fall period and the average yearly BOD_5 value of 9.6 mg/L present during the current year was the highest observed since the study was first implemented in 1972 (Table 27).

Average nitrate concentrations fell to 2.8 mg/L (as N), their lowest level since 1976, and were below detection limits (0.1 mg/L as N) in most samples from June through early October when river flows were far below normal. This is in marked contrast to the comparable period in 1986 when flows were well above normal and nitrate concentrations averaged 6.8 mg/L (as N). The impacts of low flow on the levels of several parameters related to runoff, i.e. turbidity, phosphate and nitrate are especially evident when relative loading values obtained by multiplying average concentrations by cumulative runoff are compared (Table 28).

One unexpected effect of the extended dry period which was first observed in 1987 and continued during 1988 was the unusually low levels of several parameters observed during the summer. In the past, low total alkalinity, hardness, and dissolved solids values usually occurred during periods of snowmelt and runoff, or following extended periods of rainfall. However, in 1988 lowest levels of these substances were generally observed from late May through October during the extended dry period. It appears that these low values were probably the result of the rapid downward movement of surface water through the dry unconsolidated surficial deposits into the shallow aquifers feeding the Cedar River. This rapid movement of water shortens its residence time in the surface deposits and shallow aquifer, and reduces the time available for the solubilization of calciferous materials. A similar pattern was observed in the Iowa River in 1987 and 1988.[19,20]

As in previous years, the operation of the Duane Arnold Energy Center appeared to have an insignificant impact on the fish or other aquatic organisms found in the Cedar River. Fish impingement rates were somewhat above those present in 1986 and 1987 but continued to be below levels that would adversely effect the river fishery.

The benthic community of the Cedar River in the vicinity of the Duane Arnold Energy Center has been characterized by low diversity and productivity throughout the entire study period and the absence of organisms in bottom samples taken in 1988 is not unusual. This condition is unrelated to either station operation or poor water quality, however. The river bottom in the vicinity of the Duane Arnold Energy Center is characterized by a shifting sand and silt substrate, which is not conducive to the development of a diverse or productive benthic community. When artificial substrates (Hester-Dendy) are placed in the river, however, they develop populations which are characterized by relatively high species diversity and many organisms indicative of relatively good water quality. Substrates upstream and downstream of the stations supported populations exhibiting similar composition and diversity indicating that station operation is not adversely impacting the benthic community of the Cedar River.

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Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1988

Date	Mean Monthly Discharge (cfs)	Percent of 1951-1980 Median Discharge
January	1,897	182
February	2,002	164
March	3,974	75
April	3,017	52
May	2,805	66
June	1,118	26
July	789	24
August	581	29
September	538	30
October	517	38
November	719	39
December	595	47

*Data obtained from U.S. Geological Survey records.

Table 2

Temperature (^{o}C) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0.0	0.0	14.0	4.0	0.0
Jan 28	0.0	0.0	18.0	2.5	0.5
Feb 11	0.0	0.0	15.0	1.5	0.0
Feb 25	0.0	0.0	0.5	0.5	0.0
Mar 09	2.0	2.0	3.0	2.0	2.0
Mar 24	7.0	8.0	22.0	7.5	9.0
Apr 07	12.0	12.0	24.0	13.0	13.0
Apr 21	11.0	11.0	11.0	11.0	11.0
May 12	21.0	21.5	26.5	21.5	23.0
May 26	21.5	20.5	20.5	20.5	21.5
Jun 08	25.5	25.5	29.0	27.0	27.0
Jun 27	25.0	25.0	26.5	26.0	26.0
Jul 14	28.0	28.0	29.0	28.0	28.0
Jul 26	25.0	26.0	24.0	25.0	26.0
Aug 12	27.0	27.0	31.5	28.0	29.0
Aug 26	22.0	22.5	27.0	22.5	24.0
Sep 08	19.0	19.0	25.0	20.0	21.0
Sep 22	20.0	20.0	28.0	21.0	22.0
Oct 06	11.0	11.5	17.0	14.0	12.5
Oct 20	10.0	10.0	10.5	10.0	10.0
Nov 02	5.0	5.0	11.0	5.5	6.5
Nov 17	4.0	4.0	10.0	5.5	4.5
Dec 08	0.0	0.5	4.0	1.5	0.5
Dec 21	0.5	0.5	4.0	3.0	1.0

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling During 1988

Date	ΔT (°C) U/S River (Sta. 2) vs. Discharge (Sta. 5)	ΔT (°C) U/S River (Sta. 2) vs. D/S River (Sta. 3)	ΔT(°C) U/S River (Sta. 2) vs. D/S River (Sta. 4)	Station Output (% full power)
Jan 14	14.0	4.0	0.0	100
Jan 28	18.0	2.5	0.5	100
Feb 11	15.0	1.5	0.0	100
Feb 25	0.5	0.5	0.0	100
Mar 09	1.0	0.0	0.0	100
Mar 24	14.0	-0.5	1.0	100
Apr 07	12.0	1.0	1.0	100
Apr 21	0.0	0.0	0.0	100
May 12	5.0	0.0	1.5	100
May 26	0.0	0.0	1.0	100
Jun 08	3.5	1.5	1.5	100
Jun 27	1.5	1.0	1.5	100
Jul 14	1.0	0.0	0.0	100
Jul 26	-2.0	-1.0	0.0	0
Aug 12	4.5	1.0	2.0	94
Aug 26	4.5	0.0	1.5	0
Sep 08	6.0	1.0	2.0	90
Sep 22	8.0	1.0	2.0	90
Oct 06	5.5	3.5	1.0	0
Oct 20	0.5	0.0	0.0	0
Nov 02	6.0	0.5	1.5	0
Nov 17	6.0	1.5	0.5	0
Dec 08	3.5	1.0	0.0	0
Dec 21	3.5	2.5	0.5	0

Table 4

Turbidity (NTU) Values from the Cedar River
Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
			Sampling Locations		
Jan 14	5	6	15	9	7
Jan 28	4	3	19	7	5
Feb 11	4	3	23	7	5
Feb 25	17	17	18	18	18
Mar 09	77	77	76	78	72
Mar 24	27	28	97	44	29
Apr 07	34	47	130	56	56
Apr 21	26	26	26	29	24
May 12	50	55	170	60	45
May 26	43	38	35	38	34
Jun 08	68	59	80	72	61
Jun 27	36	25	150	66	32
Jul 14	49	50	37	66	58
Jul 26	36	37	68	49	53
Aug 12	8	4	8	3	9
Aug 26	35	33	370	38	38
Sep 08	27	25	80	31	29
Sep 22	23	23	71	28	28
Oct 06	28	30	18	26	25
Oct 20	21	22	23	21	20
Nov 02	17	18	5	17	19
Nov 17	23	19	11	17	18
Dec 08	14	13	32	9	9
Dec 21	9	12	11	11	13

Table 5

Total Solids (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	400	380	1200	660	450
Jan 28	380	380	1180	510	380
Feb 11	380	380	1740	540	390
Feb 25	310	300	310	300	290
Mar 09	420	420	420	420	390
Mar 24	410	410	2400	860	450
Apr 07	400	410	1500	480	460
Apr 21	350	380	370	380	370
May 12	460	450	1500	500	450
May 26	360	360	380	390	370
Jun 08	340	310	1300	690	380
Jun 27	290	270	1300	940	300
Jul 14	320	320	320	340	380
Jul 26	270	*	380	330	330
Aug 12	290	180	1600	300	310
Aug 26	300	290	2200	330	280
Sep 08	320	310	1500	340	340
Sep 22	320	320	1500	340	380
Oct 06	290	270	990	540	310
Oct 20	290	260	270	280	280
Nov 02	330	360	1900	380	350
Nov 17	390	370	360	380	350
Dec 08	390	400	430	370	400
Dec 21	420	420	400	400	430

*Lab accident

Table 6

Dissolved Solids (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	400	380	1200	610	410
Jan 28	350	340	1100	460	350
Feb 11	350	340	1650	510	380
Feb 25	260	280	280	280	280
Mar 09	260	250	270	260	250
Mar 24	350	320	2200	740	370
Apr 07	310	300	1200	360	340
Apr 21	250	290	260	290	270
May 12	330	320	1200	360	340
May 26	230	220	270	240	230
Jun 08	210	210	1100	510	290
Jun 27	170	180	990	800	200
Jul 14	180	180	220	180	200
Jul 26	160	170	210	200	180
Aug 12	200	180	1400	210	210
Aug 26	220	220	1300	250	210
Sep 08	160	160	1300	180	190
Sep 22	140	240	1200	280	280
Oct 06	220	200	960	460	230
Oct 20	230	200	250	220	220
Nov 02	300	290	1800	330	300
Nov 17	330	320	320	330	310
Dec 08	360	350	340	350	370
Dec 21	390	390	370	360	380

Table 7

Suspended Solids (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	8	8	22	14	11
Jan 28	3	3	27	9	6
Feb 11	4	5	26	8	5
Feb 25	15	15	17	18	9
Mar 09	150	150	140	160	140
Mar 24	54	59	170	82	54
Apr 07	69	93	270	110	110
Apr 21	84	88	81	70	80
May 12	120	100	280	130	100
May 26	94	120	100	120	110
Jun 08	110	100	140	120	83
Jun 27	100	64	280	110	77
Jul 14	110	120	74	150	140
Jul 26	90	96	140	110	120
Aug 12	56	80	140	88	84
Aug 26	68	62	680	80	64
Sep 08	72	76	140	96	82
Sep 22	72	68	150	60	72
Oct 06	62	66	20	52	56
Oct 20	54	40	34	36	38
Nov 02	26	39	4	33	43
Nov 17	50	37	16	37	39
Dec 08	18	23	87	16	23
Dec 21	16	22	18	22	24

Table 8

Dissolved Oxygen (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	11.4	12.3	9.8	12.6	12.4
Jan 28	11.6	11.4	9.5	11.4	11.4
Feb 11	10.2	10.1	8.6	10.0	11.0
Feb 25	10.6	9.6	12.0	11.8	10.6
Mar 09	11.6	11.2	12.2	11.4	11.6
Mar 24	10.6	11.2	8.4	11.0	11.9
Apr 07	11.5	11.6	9.2	10.8	11.2
Apr 21	13.4	13.8	11.8	13.1	14.4
May 12	9.1	9.4	7.2	9.5	9.4
May 26	11.6	12.1	9.7	11.0	12.2
Jun 08	11.2	10.5	6.2	9.5	11.1
Jun 27	10.6	11.3	4.5	6.5	11.2
Jul 14	9.3	10.2	7.6	10.8	12.0
Jul 26	8.4	8.7	6.9	8.3	10.3
Aug 12	9.0	9.2	5.5	10.0	11.6
Aug 26	12.9	14.3	7.4	13.8	13.2
Sep 08	11.4	12.0	7.2	11.9	12.5
Sep 22	11.8	12.8	9.1	14.0	13.9
Oct 06	15.5	15.6	11.8	16.2	16.4
Oct 20	12.7	12.6	12.0	12.9	13.4
Nov 02	15.1	16.0	11.4	15.9	17.4
Nov 17	13.8	14.2	13.4	14.2	14.2
Dec 08	15.4	15.4	13.8	15.4	15.6
Dec 21	18.6	19.3	14.4	16.3	17.5

Table 9

Carbon Dioxide (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	20	20	*	8	12
Jan 28	14	14	*	10	12
Feb 11	17	10	*	11	13
Feb 25	8	10	5	9	7
Mar 09	6	5	4	5	5
Mar 24	3	3	*	3	3
Apr 07	2	3	3	3	2
Apr 21	<1	<1	<1	<1	<1
May 12	<1	<1	*	<1	<1
May 26	<1	<1	<1	<1	<1
Jun 08	<1	<1	1	<1	<1
Jun 27	<1	<1	1	1	<1
Jul 14	<1	<1	1	<1	<1
Jul 26	<1	<1	1	<1	<1
Aug 12	<1	<1	*	<1	<1
Aug 26	<1	<1	*	<1	<1
Sep 08	<1	<1	*	<1	<1
Sep 22	<1	<1	*	<1	<1
Oct 06	<1	<1	<1	<1	<1
Oct 20	<1	<1	<1	<1	<1
Nov 02	<1	<1	*	<1	<1
Nov 17	<1	<1	<1	<1	<1
Dec 08	<1	<1	<1	<1	<1
Dec 21	<1	<1	<1	<1	<1

*Unable to calculate

Table 10

Total Alkalinity (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	264	260	200	246	258
Jan 28	236	238	130	216	238
Feb 11	228	222	108	212	222
Feb 25	168	166	162	162	166
Mar 09	148	146	142	138	140
Mar 24	226	212	108	190	212
Apr 07	206	206	136	202	206
Apr 21	152	148	152	152	148
May 12	200	202	136	190	194
May 26	128	120	126	120	124
Jun 08	116	104	88	100	108
Jun 27	120	124	148	148	124
Jul 14	116	110	110	112	114
Jul 26	74	72	106	86	62
Aug 12	62	72	68	70	80
Aug 26	130	122	142	122	118
Sep 08	100	94	88	94	96
Sep 22	124	120	80	124	118
Oct 06	108	108	336	202	112
Oct 20	122	124	124	126	126
Nov 02	178	178	*	174	176
Nov 17	196	186	192	192	180
Dec 08	224	224	228	224	222
Dec 21	230	226	226	228	228

*pH too low to determine alkalinity

Table 11

Carbonate Alkalinity (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	<1	<1	<1	<1	<1
Jan 28	<1	<1	<1	<1	<1
Feb 11	<1	<1	<1	<1	<1
Feb 25	<1	<1	<1	<1	<1
Mar 09	<1	<1	<1	<1	<1
Mar 24	<1	<1	<1	<1	<1
Apr 07	<1	<1	<1	<1	<1
Apr 21	4	4	4	6	8
May 12	8	8	<1	10	10
May 26	8	8	6	8	12
Jun 08	8	8	<1	6	8
Jun 27	10	12	<1	<1	14
Jul 14	4	6	<1	10	14
Jul 26	16	18	<1	8	16
Aug 12	20	6	<1	16	12
Aug 26	24	20	<1	22	22
Sep 08	36	22	<1	26	24
Sep 22	14	14	<1	14	16
Oct 06	16	16	70	20	18
Oct 20	6	6	4	6	8
Nov 02	4	6	*	6	6
Nov 17	12	12	8	10	12
Dec 08	6	6	4	8	6
Dec 21	10	12	6	8	10

*pH too low to determine alkalinity

Table 12

Units of pH from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	7.6	7.6	8.1	7.9	7.8
Jan 28	7.7	7.7	8.0	7.8	7.8
Feb 11	7.6	7.8	7.8	7.7	7.7
Feb 25	7.8	7.7	8.0	7.8	7.9
Mar 09	7.8	7.9	8.0	7.9	7.9
Mar 24	8.2	8.2	7.8	8.2	8.2
Apr 07	8.3	8.2	7.8	8.2	8.3
Apr 21	8.4	8.5	8.6	8.6	8.6
May 12	8.6	8.6	8.0	8.6	8.6
May 26	9.0	9.0	9.0	9.0	9.2
Jun 08	9.0	9.1	7.9	8.8	9.2
Jun 27	9.3	9.3	8.3	8.4	9.4
Jul 14	8.6	8.7	8.3	8.8	8.9
Jul 26	9.2	9.2	8.3	8.9	9.2
Aug 12	9.3	9.4	8.0	9.4	9.5
Aug 26	9.2	9.2	7.9	9.2	9.2
Sep 08	9.4	9.4	8.4	9.5	9.5
Sep 22	9.2	9.2	8.3	9.3	9.3
Oct 06	9.3	9.4	9.9	9.5	9.4
Oct 20	9.0	9.0	8.9	9.0	9.1
Nov 02	8.8	8.8	3.3	8.8	8.9
Nov 17	8.5	8.7	8.5	8.8	8.8
Dec 08	8.8	8.8	8.5	8.7	8.8
Dec 21	9.0	9.0	8.7	8.8	9.1

Table 13

Total Hardness (mg/L-$CaCO_3$) from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	360		880	498	395
Jan 28	315	315	755	415	325
Feb 11	354	346	1150	442	362
Feb 25	236	228	258	242	220
Mar 09	190	190	200	190	180
Mar 24	292	326	1450	548	374
Apr 07	374	302	862	338	340
Apr 21	226	226	290	222	266
May 12	274	272	525	205	192
May 26	180	195	90	90	80
Jun 08	370	250	670	400	340
Jun 27	198	160	646	496	182
Jul 14	195	145	190	170	150
Jul 26	144	136	214	174	148
Aug 12	144	144	770	146	160
Aug 26	164	164	840	170	170
Sep 08	156	200	910	388	189
Sep 22	310	225	695	230	200
Oct 06	178	162	98	142	142
Oct 20	100	172	260	198	224
Nov 02	236	228	478	254	224
Nov 17	254	302	254	248	260
Dec 08	340	356	324	330	356
Dec 21	312	310	285	300	306

Table 14

Calcium Hardness (mg/L-$CaCO_3$) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	280	230	615	325	250
Jan 28	200	190	490	260	220
Feb 11	221	208	778	285	226
Feb 25	166	158	158	150	192
Mar 09	130	140	140	130	140
Mar 24	220	208	980	378	210
Apr 07	210	212	598	248	216
Apr 21	144	152	142	142	126
May 12	178	188	525	205	192
May 26	90	90	90	90	80
Jun 08	120	110	320	200	90
Jun 27	82	98	292	234	88
Jul 14	60	50	37	66	58
Jul 26	45	37	68	49	53
Aug 12	64	62	415	74	66
Aug 26	85	85	443	38	38
Sep 08	80	60	380	64	72
Sep 22	85	90	460	95	95
Oct 06	65	80	2	60	65
Oct 20	54	122	75	102	110
Nov 02	144	172	338	144	132
Nov 17	162	160	164	170	162
Dec 08	208	200	191	214	191
Dec 21	225	208	225	205	198

Table 15

Total Phosphorus (mg/L-P) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	0.2	0.2	1.3	0.4	0.2
Jan 28	0.6	0.6	1.7	0.8	0.6
Feb 11	0.3	0.3	1.4	0.4	0.3
Feb 25	0.5	0.4	0.5	0.5	0.5
Mar 09	0.4	0.4	0.5	0.4	0.4
Mar 24	0.2	0.2	2.5	0.2	0.5
Apr 07	0.3	0.3	1.4	0.3	0.3
Apr 21	0.1	<0.1	0.1	<0.1	0.2
May 12	0.1	0.2	0.8	0.2	0.2
May 26	0.1	0.2	0.2	0.2	0.1
Jun 08	0.3	0.3	2.4	1.0	0.4
Jun 27	0.3	0.3	2.2	3.3	0.4
Jul 14	0.3	0.3	0.3	0.3	0.2
Jul 26	0.2	0.2	0.7	0.6	0.2
Aug 12	0.2	0.2	2.1	0.3	0.2
Aug 26	0.3	0.4	2.5	0.4	0.4
Sep 08	0.5	0.5	0.6	0.6	1.7
Sep 22	0.3	0.3	0.4	0.3	1.4
Oct 06	0.4	0.3	120	0.4	1.2
Oct 20	0.3	0.4	0.4	0.3	0.4
Nov 02	0.3	0.3	0.5	0.3	0.2
Nov 17	0.2	0.2	0.2	0.2	0.3
Dec 08	0.4	0.4	0.4	0.3	0.4
Dec 21	0.3	0.4	0.2	0.2	0.3

Table 16

Soluble Orthophosphate (mg/L-P) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
			Sampling Locations		
Jan 14	0.2	0.2	0.8	0.3	0.2
Jan 28	0.2	0.2	0.7	0.3	0.2
Feb 11	0.3	0.2	0.8	0.3	0.3
Feb 25	0.4	0.4	0.4	0.4	0.4
Mar 09	0.3	0.3	0.4	0.3	0.3
Mar 24	0.1	0.2	1.4	0.2	0.2
Apr 07	0.2	0.2	0.6	0.1	0.1
Apr 21	<0.1	<0.1	0.1	<0.1	0.2
May 12	<0.1	<0.1	0.8	0.1	<0.1
May 26	<0.1	<0.1	<0.1	<0.1	<0.1
Jun 08	<0.1	<0.1	0.8	0.3	0.1
Jun 27	<0.1	<0.1	1.0	0.7	<0.1
Jul 14	<0.1	<0.1	<0.1	<0.1	<0.1
Jul 26	<0.1	<0.1	<0.1	<0.1	<0.1
Aug 12	<0.1	<0.1	0.9	<0.1	<0.1
Aug 26	<0.1	<0.1	0.8	<0.1	<0.1
Sep 08	<0.1	<0.1	0.1	<0.1	<0.1
Sep 22	<0.1	<0.1	0.2	<0.1	<0.1
Oct 06	<0.1	<0.1	2.8	<0.1	<0.1
Oct 20	0.1	<0.1	<0.1	<0.1	<0.1
Nov 02	<0.1	<0.1	0.1	<0.1	<0.1
Nov 17	<0.1	<0.1	<0.1	<0.1	<0.1
Dec 08	0.2	0.2	0.1	0.2	0.2
Dec 21	0.1	0.1	0.1	0.2	0.1

Table 17

Ammonia (mg/L-N) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	0.1	0.2	<0.1	<0.1	0.2
Jan 28	0.4	0.3	<0.1	0.2	0.3
Feb 11	0.4	0.3	<0.1	0.4	0.4
Feb 25	0.6	0.6	0.6	0.6	0.6
Mar 09	0.4	0.4	0.4	0.4	0.6
Mar 24	<0.1	<0.1	<0.1	<0.1	<0.1
Apr 07	<0.1	<0.1	<0.1	<0.1	<0.1
Apr 21	<0.1	<0.1	<0.1	<0.1	0.1
May 12	<0.1	<0.1	<0.1	<0.1	<0.1
May 26	<0.1	<0.1	<0.1	<0.1	<0.1
Jun 08	<0.1	<0.1	0.1	<0.1	<0.1
Jun 27	<0.1	<0.1	0.3	0.2	<0.1
Jul 14	<0.1	<0.1	<0.1	<0.1	<0.1
Jul 26	<0.1	<0.1	<0.1	<0.1	<0.1
Aug 12	<0.1	<0.1	0.2	<0.1	<0.1
Aug 26	<0.1	<0.1	0.1	<0.1	<0.1
Sep 08	<0.1	<0.1	<0.1	<0.1	<0.1
Sep 22	<0.1	<0.1	<0.1	<0.1	<0.1
Oct 06	<0.1	<0.1	<0.1	<0.1	<0.1
Oct 20	<0.1	<0.1	<0.1	<0.1	<0.1
Nov 02	<0.1	<0.1	0.7	<0.1	<0.1
Nov 17	<0.1	<0.1	0.2	<0.1	<0.1
Dec 08	<0.1	<0.1	<0.1	<0.1	<0.1
Dec 21	<0.1	<0.1	<0.1	<0.1	<0.1

Table 18

Nitrate (mg/L-N) Values from the Cedar River
Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	7.9	7.9	18.0	9.9	8.2
Jan 28	6.8	6.6	14.0	8.2	7.2
Feb 11	6.4	6.3	22.0	8.2	6.8
Feb 25	4.7	4.5	4.7	4.6	4.7
Mar 09	4.7	4.7	4.8	4.6	4.7
Mar 24	5.3	5.4	25.0	6.6	5.8
Apr 07	6.4	6.5	16.0	6.7	6.9
Apr 21	3.6	3.7	3.8	3.7	3.7
May 12	5.4	5.4	13.0	5.4	5.8
May 26	2.3	2.4	2.4	2.4	2.5
Jun 08	<0.1	<0.1	0.6	<0.1	<0.1
Jun 27	0.1	0.2	0.4	0.3	0.2
Jul 14	<0.1	<0.1	<0.1	<0.1	<0.1
Jul 26	<0.1	<0.1	<0.1	<0.1	<0.1
Aug 12	<0.1	<0.1	0.7	<0.1	<0.1
Aug 26	<0.1	<0.1	0.9	<0.1	<0.1
Sep 08	<0.1	<0.1	0.2	<0.1	<0.1
Sep 22	0.2	0.2	1.2	0.2	0.2
Oct 06	<0.1	<0.1	<0.1	<0.1	<0.1
Oct 20	0.5	0.5	0.4	0.5	0.5
Nov 02	1.3	1.2	0.1	1.2	1.2
Nov 17	2.3	2.1	1.7	2.0	2.1
Dec 08	3.9	3.9	3.2	3.6	3.8
Dec 21	3.8	3.8	3.1	3.2	3.7

Table 19

Total Iron (mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	0.14	0.14	0.40	0.20	0.14
Jan 28	0.14	0.11	0.45	0.18	0.12
Feb 11	0.12	0.16	0.67	0.17	0.13
Feb 25	0.37	0.32	0.37	0.38	0.37
Mar 09	1.0	0.89	1.2	1.1	1.2
Mar 24	2.2	1.2	5.3	1.4	1.2
Apr 07	0.49	0.83	2.6	0.70	0.81
Apr 21	0.24	0.31	0.34	0.33	0.30
May 12	0.69	0.72	2.3	0.98	0.72
May 26	0.17	0.17	0.22	0.15	0.11
Jun 08	0.23	0.20	0.79	0.41	0.17
Jun 27	0.35	0.36	1.7	1.2	0.37
Jul 14	0.16	0.18	0.24	0.19	0.09
Jul 26	0.31	0.75	0.76	0.63	0.48
Aug 12	0.14	0.16	1.0	0.13	2.1
Aug 26	0.20	0.20	1.2	0.28	0.22
Sep 08	0.16	0.19	1.1	0.22	0.18
Sep 22	0.17	0.16	1.1	0.17	0.22
Oct 06	0.13	0.23	0.56	0.47	0.23
Oct 20	0.11	0.11	0.13	0.13	0.12
Nov 02	0.19	0.19	6.0	0.20	0.22
Nov 17	0.38	0.25	0.28	0.22	0.25
Dec 08	0.10	0.12	0.37	0.15	0.12
Dec 21	0.08	0.07	0.13	0.14	0.08

Table 20

Biochemical Oxygen Demand (5 Day in mg/L) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

	Sampling Locations				
Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 14	1	1	3	1	1
Jan 28	<1	1	2	1	1
Feb 11	1	1	2	2	2
Feb 25	5	5	5	6	6
Mar 09	5	5	5	5	5
Mar 24	3	3	5	3	3
Apr 07	4	4	10	5	4
Apr 21	8	7	13	13	13
May 12	6	6	9	7	7
May 26	16	17	16	19	17
Jun 08	18	20	30	25	20
Jun 27	14	12	24	17	14
Jul 14	16	17	13	16	16
Jul 26	21	21	19	20	24
Aug 12	14	15	26	16	17
Aug 26	12	14	35	14	14
Sep 08	20	22	35	22	22
Sep 22	12	10	18	11	11
Oct 06	19	20	19	16	20
Oct 20	14	14	14	14	14
Nov 02	9	10	1	9	10
Nov 17	6	7	5	6	6
Dec 08	5	5	5	4	5
Dec 21	7	8	6	6	7

Table 21

Coliform Bacteria (Total Org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan 14	3100	2700	1100	2200	1300
Jan 28	3200	1200	1000	2500	700
Feb 11	2500	1900	800	2000	2300
Feb 25	3800	3900	9000	4100	3300
Mar 09	700	700	900	1800	1000
Mar 24	280	270	200	210	120
Apr 07	1600	1300	2200	2400	1500
Apr 21	300	900	400	600	500
May 12	1000	1100	700	1100	900
May 26	100	100	200	200	300
Jun 08	300	100	*	27,000	2900
Jun 27	200	100	3000	1000	100
Jul 14	150	150	10,000	400	500
Jul 26	10	*	*	200	100
Aug 12	300	*	800	800	200
Aug 26	100	100	*	80	120
Sep 08	100	20	360	80	140
Sep 22	580	340	1500	200	440
Oct 06	30	130	180	130	60
Oct 20	440	180	180	400	320
Nov 02	200	190	<10	140	200
Nov 17	1500	1100	800	560	660
Dec 08	130	50	320	90	90
Dec 21	150	130	200	120	60

*Unable to quantify

Table 22

Coliform Bacteria (Fecal Org/100 ml) Values from the Cedar River Near the Duane Arnold Energy Center During 1988

Date 1988	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 ft. Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
			Sampling Locations		
Jan 14	660	290	180	250	160
Jan 28	1000	310	150	370	170
Feb 11	680	610	290	400	400
Feb 25	1200	1200	810	1100	710
Mar 09	70	90	80	150	110
Mar 24	<10	10	30	<10	10
Apr 07	100	70	300	60	70
Apr 21	10	<10	20	20	<10
May 12	>0	100	400	80	20
May 26	<10	10	100	20	10
Jun 08	30	*	*	*	2000
Jun 27	20	20	*	*	*
Jul 14	60	50	*	*	*
Jul 26	*	100	*	*	100
Aug 12	*	20	100	*	*
Aug 26	50	80	*	*	*
Sep 08	20	40	120	*	*
Sep 22	300	290	1000	120	300
Oct 06	30	20	90	90	20
Oct 20	10	10	10	40	<10
Nov 02	10	20	<10	<10	<10
Nov 17	410	160	160	200	190
Dec 08	10	<10	20	<10	<10
Dec 21	10	20	10	<10	<10

*Unable to quantify

Table 23

Quarterly Chemical Analysis - 1988

Station	Cl^- (mg/L)	SO_4^{-2} (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			March 23					
1. Lewis Access	22	36	<10	<10	<10	140	<1	<20
2. Upstream DAEC	22	40	<10	<10	<10	80	<1	<20
3. Downstream DAEC	40	110	<10	<10	<10	100	<1	<20
4. One-half mile below plant	25	60	<10	<10	<10	70	<1	30
5. Discharge canal	99	1100	20	80	10	280	<1	510
			June 27					
1. Lewis Access	24	33	<20	<10	<10	120	<1	<20
2. Upstream DAEC	24	36	<20	<10	<10	110	<1	<20
3. Downstream DAEC	100	340	<20	20	<10	350	<1	310
4. One-half mile below plant	28	52	<20	<10	<10	130	<1	80
5. Discharge canal	130	460	<20	30	<10	410	<1	460

Table 24
Benthic Macroinvertebrates Collected from the
Cedar River and Discharge Canal near the Duane Arnold Energy Center
31 May 1988 to 15 July 1988

	Artificial Substrate Collections														
	Lewis Access			Upstream DAEC			Downstream D			½ mi below plant			Discharge Canal		
Taxon	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera															
Hydropsychidae	-	-		288	304	128				148	80	36	12	2	16
Hydropsyche bidens	-	-		2024	1516	1028				900	1112	80	17	8	57
Hydropsyche orris	-	-		1312	868	488				620	460	36	19	5	27
Cheumatopsyche sp.	-	-		152	128	88				56	56	36	-	-	-
Diptera															
Chironomidae (larvae/pupae)	98	255		216	600	180				788	804	5712	742	730	887
Hemerodromia sp.	-	-		-	4	-				-	-	-	-	-	-
Atherix sp.	-	-		-	4	-				-	-	-	-	-	-
Anthomyidae	91	14		-	-	-				-	-	-	-	-	-
Tulipidae	1	-		-	-	-									
Ephemeroptera															
aetidae	-	-		32	32	-				4	4	-	5	5	7
Ameletus sp.	-	-		-	16	20				4	-	-	3	-	-
Caenidae	-	-		-	-	-				4	-	-	-	-	-
Caenis sp.	-	-		4	24	4				8	12	32	1	-	-
Tricorythodes sp.	-	-		-	4	-				-	-	4	1	1	
Stenonema sp.	-	-		-	-	-				-	-	4	-	-	-
Coleoptera															
Elmidae	-	-		12	-	-				4	4	-	1	1	-
Stenelmis sp.	11	12		-	-	-				-	-	-	-	-	-
Carabidae	1	-		-	-	-				-	-	-	-	-	-
Laccobius sp.	1	1		-	-	-				-	-	-	-	-	-
Tropisternus sp.	2	-		-	-	-				-	-	-	-	-	-
Laccophilus sp.	1	1		-	-	-				-	-	-	-	-	-
Odonata															
Argia sp.	-	-		-	-	-				-	-	-	-	1	1
Megaloptera															
Sialis sp.	-	-		-	-	-				-	-	-	1	-	3
Gastropoda															
Physa sp.	-	-		-	4	-				-	-	-	103	64	90
Turbellaria															
Planariidae sp.	-	-		-	-	-				-	-	-	1	-	-
Hirudinea	-	-		-	-	-				-	-	-	1	-	1
Total No. of Organisms	206	283		4040	3504	1936				2536	2532	5940	907	817	1087
Total No. of Species	8	5		8	12	7				10	8	8	13	9	9

Note: to convert no. of organisms counted to No./m^2 multiply by 6.25.

Table 24 (cont.)
Benthic Macroinvertebrates Collected from the
Cedar River and Discharge Canal near the Duane Arnold Energy Center
22 September 1988 to 3 November 1988

Taxon	Artificial Substrate Collections: Lewis Access A	B	C	Upstream DAEC A	B	C	Downstream DA A	B	C	½ mi below plt A	B	C	Discharge Canal A	B	C
Trichoptera															
Hydropsychidae	20	20	125	794	1708	692	-	-	3	385	360	128	-	4	-
Hydropsyche bidens	6	22	102	199	412	220	-	4	5	47	156	21	-	2	-
Hydropsyche orris	20	18	129	725	868	348	-	3	2	98	100	12	-	2	-
Hydropsyche simulans	-	-	-	24	-	-	-	1	-	-	-	-	-	-	-
Cheumatopsyche sp.	1	-	13	20	24	20	-	-	1	15	16	3	-	-	-
Diptera															
Chironomidae	45	243	343	1028	1840	680	54	45	54	257	740	191	27	24	32
Atherix sp.	-	-	1	-	-	4	-	-	-	-	-	-	-	-	-
Simulium sp.	-	2	-	8	24	-	-	-	-	4	8	-	-	-	1
Tulipidae	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-
Ephemeroptera															
Tricorythodes sp.	-	-	1	2	4	-	-	-	1	1	4	-	-	-	-
Heptageniidae	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptagenia sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Stenonema sp.	7	13	45	30	88	32	-	3	1	38	68	11	-	-	-
Stenonema femoratum	-	3	3	25	28	40	-	1	-	11	12	16	-	-	-
Stenocron sp.	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-
Potamanthus sp.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Coleoptera															
Stenelmis sp.	-	-	-	2	4	4	-	-	-	-	-	-	-	-	-
Tropisternus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Plecoptera															
Pteronarcys sp.	45	39	205	402	660	168	1	1	2	68	248	61	-	-	-
Neoperla sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Odonata															
Argia sp.	1	-	-	-	-	-	4	-	4	-	-	1	18	22	44
Megaloptera															
Corydalus cornutus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera															
Belostoma sp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Gastropoda															
Physa sp.	-	-	-	-	-	-	27	19	41	-	-	-	311	422	317
Turbellaria															
Planariidae	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Annelida															
Naididae	-	-	-	-	-	-	1	-	-	-	-	-	-	33	-
Pelecypoda															
Unionidae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Total No. of Organisms	147	362	968	3262	5660	2208	106	78	125	924	1712	445	356	509	395
Total No. of Species	9	10	11	14	11	10	7	9	11	10	10	10	3	7	5

Note: to convert no. of organisms counted to No./m^2 multiply by 6.25.

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January - December 1988

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	10	0	0	0	0	0	0	0	0	9
2	0	0	1	0	0	0	0	0	0	0	0	2
3	3	0	1	2	0	1	1	1	0	0	3	2
4	0	0	0	4	0	0	0	0	0	0	0	3
5	1	0	4	0	0	0	0	0	0	0	1	6
6	0	0	4	2	0	0	0	2	0	0	1	30
7	0	0	7	4	0	0	0	0	0	0	4	15
8	1	0	24	1	0	0	0	0	0	0	8	2
9	0	3	31	2	1	0	0	0	0	0	3	3
10	0	0	4	2	0	0	1	0	0	0	1	5
11	0	0	1	0	0	0	0	0	0	0	3	3
12	0	0	1	1	0	3	0	0	0	0	5	1
13	0	0	1	1	0	0	0	0	0	0	0	13
14	1	2	2	0	0	0	0	1	0	0	2	0
15	0	0	1	1	1	1	0	0	0	0	1	2
16	2	0	2	0	0	0	0	0	0	0	9	5
17	0	0	3	1	0	0	0	0	0	0	5	3
18	0	3	8	3	0	0	0	0	0	0	1	39
19	0	0	1	0	0	2	0	0	0	1	0	0
20	4	0	9	0	0	0	0	0	0	0	0	0
21	4	0	2	0	0	2	0	0	3	1	0	0
22	0	0	1	0	0	7	2	0	2	0	0	0
23	3	0	1	0	0	0	0	0	0	0	7	6
24	1	0	4	1	0	0	0	0	0	0	3	0
25	0	0	5	3	0	0	0	0	0	2	6	0
26	3	12	1	0	0	0	0	0	0	3	4	0
27	2	6	3	0	0	0	0	0	0	1	5	4
28	0	2	1	1	0	0	1	0	0	1	1	20
29	6	2	3	0	0	0	0	0	0	1	0	0
30	5	-	2	0	0	0	0	0	0	1	3	0
31	0	-	1	-	0	-	0	0	-	3	-	10
Total	36	30	139	29	2	16	5	4	5	14	76	183

Annual Total 539

Table 26

Comparison of Average Values for Several Parameters at Upstream, Downstream and Discharge Canal Locations at the Duane Arnold Energy Center During Periods of Station Operation* - 1988

Parameter	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Mixing Zone (Sta. 3)	Downstream (Sta. 4)
Temperature (^{o}C)	13.6	19.3	15.0	14.6
Dissolved Solids (mg/L)	262	990	377	287
Total Hardness (mg/L)	235	646	314	247
Total Phosphate (mg/L)	0.30	1.15	0.58	0.48
Nitrate (mg/L as N)	3.4	7.9	3.8	3.6
Iron (mg/L)	0.33	1.25	0.50	0.51

*Excludes the period October 6 through December 21, July 26 and August 26, 1988.

Table 27

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream from the Duane Arnold Energy Center*
1972-1988

Year	Mean Flow (cfs)	Turbidity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7
1973	7,900	28	0.84	0.36	1.5	4.0
1974	5,580	29	2.10	0.17	4.2	4.7
1975	4,206	58	1.08	0.33	2.8	6.5
1976	2,082	41	0.25	0.25	2.8	7.3
1977	1,393	15	0.33	0.52	2.9	6.5
1978	3,709	23	0.26	0.22	4.4	3.3
1979	7,041	26	0.29	0.12	6.6	2.5
1980	4,523	40	0.34	0.19	5.4	4.3
1981	3,610	33	0.77	0.24	6.0	6.5
1982	7,252	43	0.56	0.23	8.0	5.1
1983	8,912	22	0.25	0.10	8.6	3.3
1984	7,325	40	0.32	0.10	5.9	3.9
1985	3,250	30	0.31	0.11	4.8	6.7
1986	6,375	33	0.26	0.10	6.8	3.7
1987	2,625	32	0.24	0.06	5.6	5.8
1988	1,546	28	0.30	<0.16	2.8	9.6

*Data from Lewis Access location (Station 1)

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Arnold Energy Center* 1972-1988

Year	Mean	Cumulative Runoff (in)	Turbidity	Relative Loading Values Total PO_4	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27

*Data from Lewis Access location (Station 1)